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AGRICULTURAL MEMORANDUM NO 515

WATERCRESS TRIALS IN HAMPSHIRE 1971-72

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Introduction

Previous work and results are described in Agr Memos Nos 330 and 384. The investigation continued in 1971-72 on the same collaborative basis with Hampshire Watercress providing the additional opportunity to study temperature changes in a commercial bed.

Meteorological Instrumentation

The main effort was directed towards a study of temperature changes in a long commercial bed and to determine whether the experimental bed results could be reliably extrapolated to commercial conditions.

Platinum resistance thermometers were exposed to record water temperatures near the inlet and at distances of 60, 180, 300 and 420 feet (outlet) down the bed.

The bed selected for this study was immediately north of the experimental bed area. The western edge was a concrete wall separating two beds, the eastern edge a concrete retaining wall through which some additional spring water entered the bed. These extra inputs must obviously affect the rate of cooling of the water, especially at times of minimum temperature. However, the positioning of the thermometers at about 10 feet from the western edge should have minimised the effects of either the nearer edge or the heat input from the springs some 30 feet away.

In addition, using resistance thermometers, measurements were made of air temperature (in a thermometer screen), water temperature in the stillage pool from which the experimental beds were fed and - mainly for the purpose of microbiological studies - inlet and outlet water temperatures in experimental beds 2 (stale water) and 3 (control).

As in 1970-71, data were recorded continuously on two Kent multi-channel recorders. Reliable, homogeneous records were available for the period November 16 to January 1.

Analysis

In Agr Memo No 384 it was tentatively suggested that cooling curves for the experimental beds could be extrapolated to longer beds by assuming that cooling beyond the first 60 feet was approximately linear and equal to the rate of fall of temperature over the distance between 40 and 60 feet from the inlet.

1. Temperature Profile

Figure 1 shows the temperature profile found for the commercial bed such that

the curve gives the ratio of the total fall in water temperature to the fall at a given distance from the inlet.

The general shape of this curve remains the same as for the experimental beds but the rate of cooling was higher than previously suggested.

Average values of $D \div D_I$ for the daily mean, maximum and minimum water temperatures are:-

	Distance from inlet in feet				
	10	60	180	300	420
Mean	7.09	4.42	1.97	1.47	1.00
Maximum	18.90	4.14	2.16	1.31	1.00
Minimum	5.51	4.53	1.91	1.57	1.00
Mean	10.50	4.36	2.01	1.45	1.00
SD	7.32	0.20	0.13	0.13	0.00

It is apparent that beyond the first 10 feet or so that the temperature profile is very similar for mean, maximum or minimum temperatures and, given a reliable estimate of outlet temperature, intermediate values of water temperature can be estimated with reasonable confidence.

2. Estimation of Outlet Temperature

The regressions found for the relationship between the difference of air and water temperatures and the fall in water temperature down the bed are:-

Mean temperature

$$D = 0.55\ D_A + 0.7$$

Maximum temperature

$$D = 0.55\ D_A + 0.2$$

Minimum temperature

$$D = 0.55\ D_A + 1.2$$

where D_A = stillage pool - air temperatures
D = stillage pool - outlet temperatures.

The standard errors of the estimates are respectively 0.9, 0.9 and 1.5°C.

Flow rates were not measured but normal commercial practice would give an average flow rate of about 350 gallons per hour per yard width and the regression found for mean temperature drop at 60 feet from the inlet

$$D_{60} = 0.10\ D_A + 0.2$$

is in reasonable agreement with previous results.

Figure 2 shows the estimated minimum water temperature at the end of the commercial bed at various minimum air temperatures as obtained from the regression.

It will be seen that if the air temperature falls to about -5°C then there is a risk of freezing damage at the outlet of a bed which is 450 feet long.

If the air temperature falls to about -10°C, then the minimum water temperature at the outlet will fall to about -2°C. Using the curve in figure 1, the distance from the inlet at which the water temperature will be 0°C is where $D \div D_I = 10 \div 12 = 1.2$, i.e. about 350 feet.

Thus if any risk of freezing damage is to be avoided, the beds at Fobdown should not exceed about 420 feet in length if the lowest air temperatures expected are about -5°C, and should not exceed about 350 feet in length if the air temperature might fall to about -10°C unless other protective measures such as increasing flow rate are possible.

A complete list of the various regressions calculated is given in appendix 1.

3. Stale Water

The stale water from the outlet of the commercial bed is pumped into a covered concrete channel and then fed into the two stale water beds. The distance the water travels under cover is only some 40-50 feet but in this time there is a considerable degree of warming. Over the period of the investigation the average warming was 1.2°C on the mean temperature and 2°C on the average minimum temperature.

The warming is negatively correlated with air temperature (correlation coefficient = -0.77) and the amount of warming can be estimated from

$$W = 1.97 - 0.17\ T^{\circ}C$$

where W = increase in mean daily water temperature from the commercial bed outlet to experimental bed inlet

T = mean daily air temperature

thus at mean air temperatures of about 10°C the warming is very small (about 0.3°C) while at mean air temperatures around 0°C the heat stored in the concrete can raise the average temperature of the water by nearly 2°C.

Conclusions

1. In a 450 foot commercial bed subject to normal (at Fobdown) management and flow rate variation the water temperature fall from well to outlet is about 6°C when the mean daily air temperature falls to around 0°C with pro rata changes at other air temperatures.

2. If the minimum air temperature falls to 0°C then the drop in water temperature would be about 7°C at minimum i.e. lowest outlet temperature of about 3°C.

3. For the outlet temperature to fall to 0°C, the minimum air temperature would have to fall to about -6°C.

4. For normal management techniques at Fobdown, the air temperature can fall to about -6°C before there is a risk of freezing damage to the crop at the bottom of a 450 foot long bed. If the air temperature falls to about -10°C then frost damage can be expected over the last 100 foot or so of the bed unless the flow rate is increased.

5. There appears to be some advantage in using covered concrete ducts between the well and bed inlets.

Any comments or suggestions on this paper should be referred to the author.

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APPENDIX 1

Regressions of water temperature change against air temperature difference from well temperatures

D_I = temperature fall to a position I-feet from the inlet.

D_A = (well-air) temperature.

	Regression	Standard error of estimate	Correlation Coefficient
Mean of 24 hourly values	$D_{10} = 0.12\ D_A - 0.10$	0.33	0.77
	$D_{60} = 0.11\ D_A + 0.23$	0.39	0.70
	$D_{180} = 0.29\ D_A + 0.30$	0.87	0.75
	$D_{300} = 0.32\ D_A + 0.76$	0.80	0.81
	$D_{420} = 0.56\ D_A + 0.66$	0.92	0.90
Minimum temperature	$D_{10} = 0.11\ D_A + 0.07$	0.49	0.69
	$D_{60} = 0.10\ D_A + 0.34$	0.59	0.60
	$D_{180} = 0.26\ D_A + 0.68$	1.28	0.66
	$D_{300} = 0.26\ D_A + 1.25$	1.16	0.70
	$D_{420} = 0.51\ D_A + 1.16$	1.48	0.83
Maximum temperature	$D_{10} = 0.13\ D_A - 0.28$	0.29	0.82
	$D_{60} = 0.12\ D_A + 0.07$	0.31	0.77
	$D_{180} = 0.29\ D_A - 0.02$	0.62	0.83
	$D_{300} = 0.35\ D_A + 0.32$	0.66	0.86
	$D_{420} = 0.54\ D_A + 0.18$	0.87	0.89

FIGURE 1

WATER TEMPERATURE PROFILE

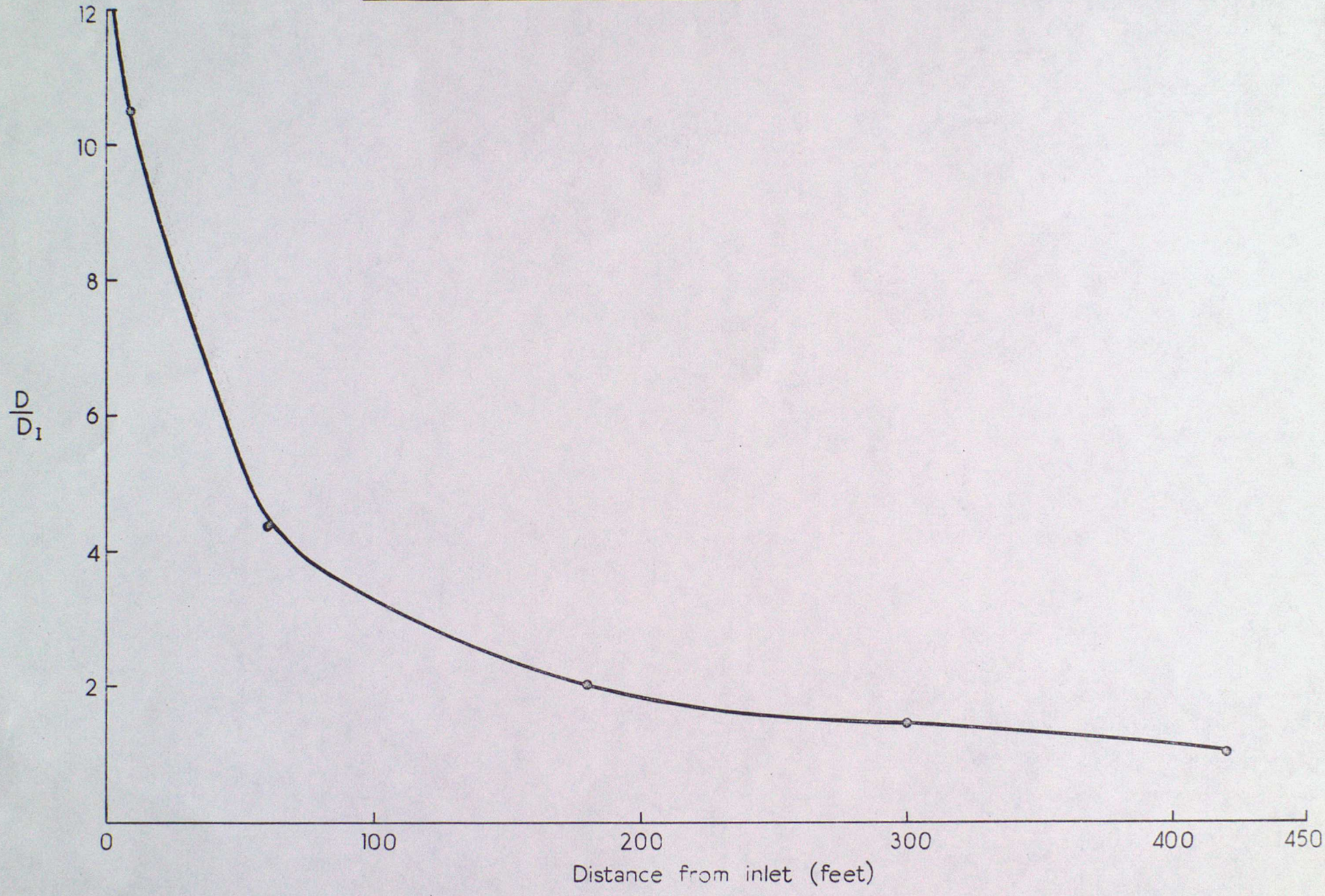

FIGURE 2

TEMPERATURE CHANGES FROM WELL TEMPERATURE

(minimum temperatures)